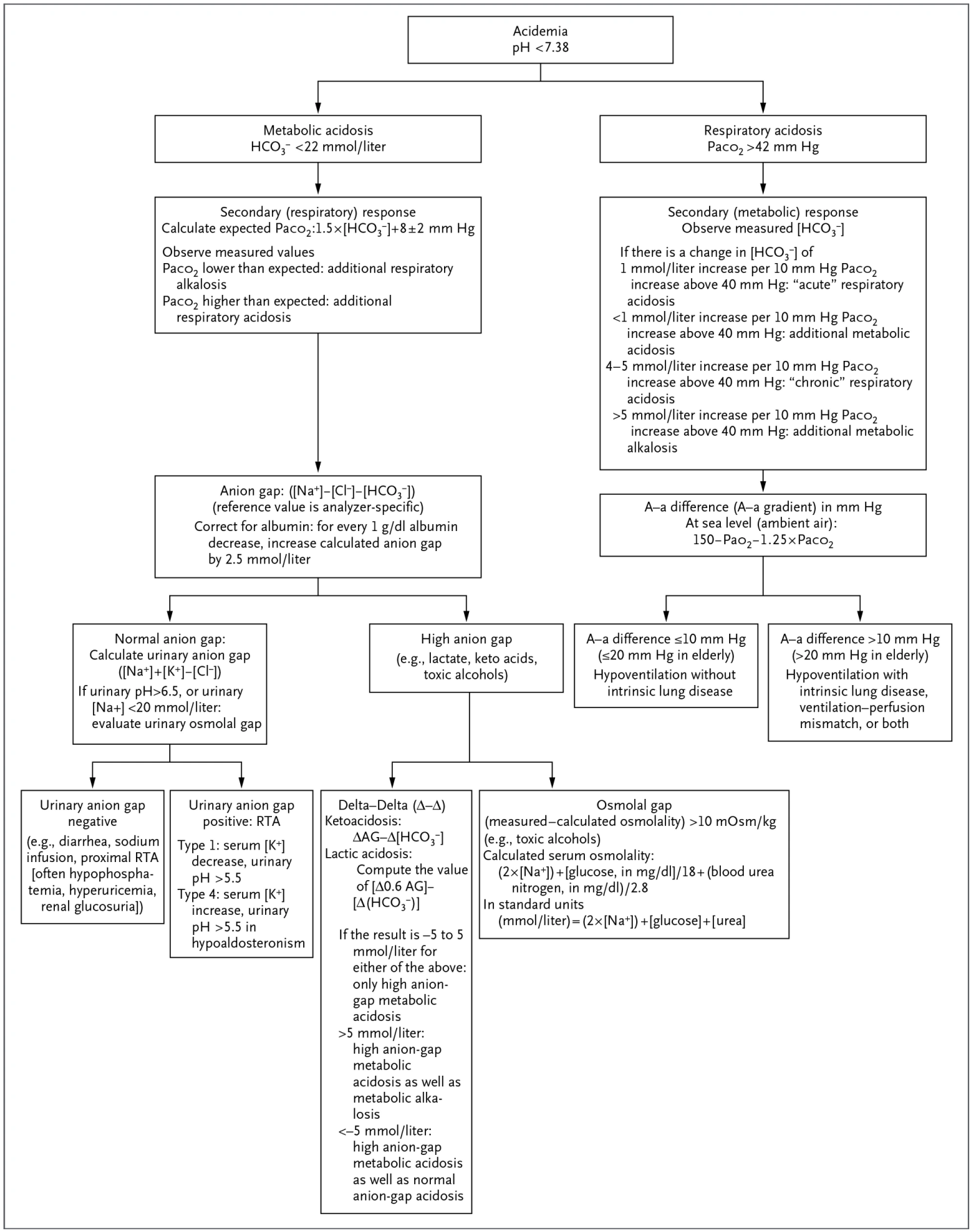
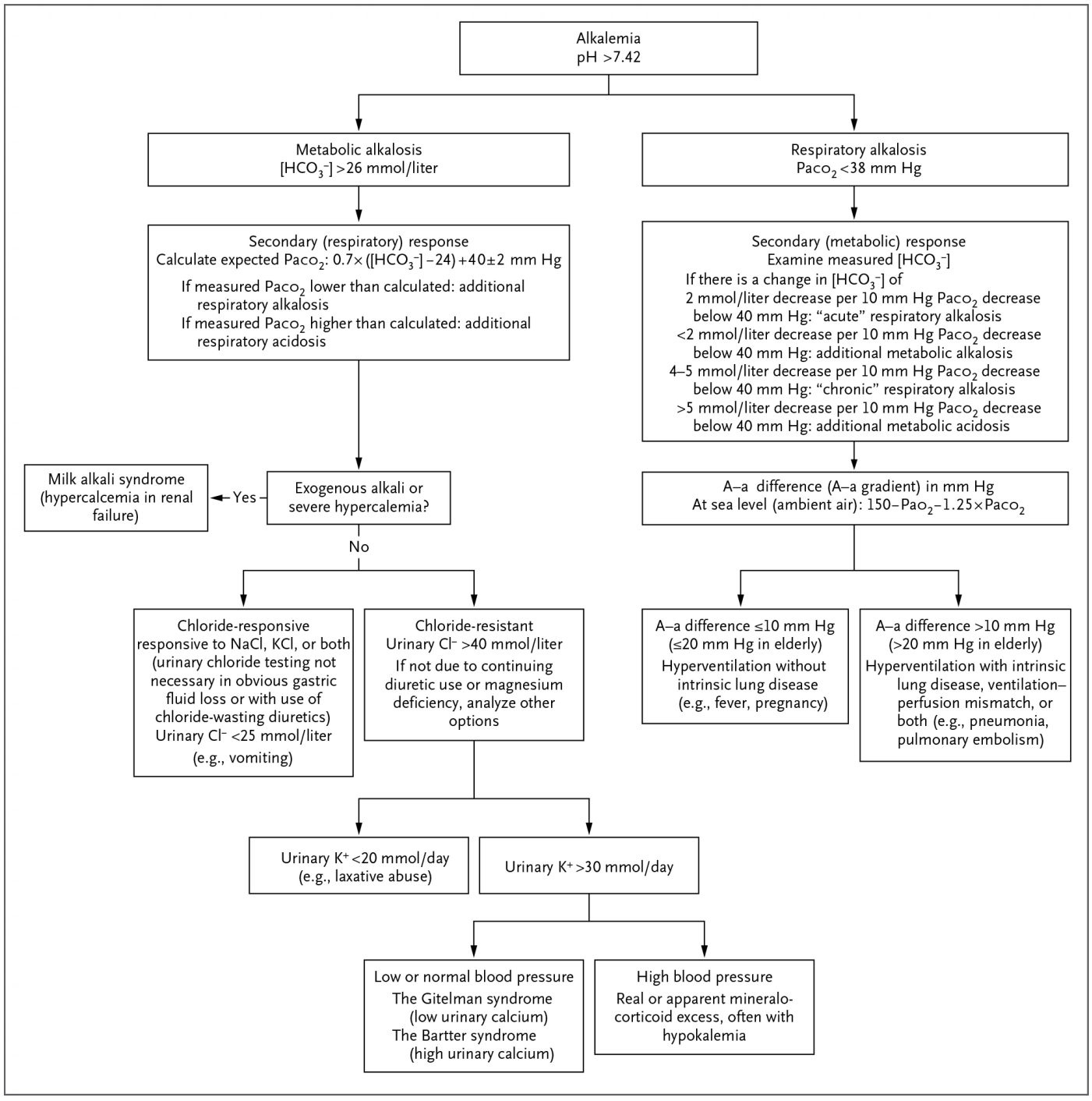
Acid–Base Disturbances

Acid–base disturbances are common in the critically ill. The NEJM review Physiological Approach to Assessment of Acid–Base Disturbances provides the following algorithms to guide the workup of alkalemia and acidemia and to assess for compensatory responses and etiology:


Acidemia
pH <7.38
Metabolic acidosis
HCO_3^- <22 mmol/liter
Respiratory acidosis
$Paco_2$ >42 mm Hg
Secondary (respiratory) response
Calculate expected $Paco_2$:1.5×[HCO_3^-]+8±2 mm Hg
Observe measured values
$Paco_2$ lower than expected: additional respiratory alkalosis
$Paco_2$ higher than expected: additional respiratory acidosis
Secondary (metabolic) response
Observe measured [HCO_3^-]
If there is a change in [HCO_3^-] of
1 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: "acute" respiratory acidosis
<1 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: additional metabolic acidosis
4–5 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: "chronic" respiratory acidosis
>5 mmol/liter increase per 10 mm Hg $Paco_2$ increase above 40 mm Hg: additional metabolic alkalosis
Anion gap: ([Na^+]–[Cl^-]–[HCO_3^-])
(reference value is analyzer-specific)
Correct for albumin: for every 1 g/dl albumin decrease, increase calculated anion gap by 2.5 mmol/liter
A–a difference (A–a gradient) in mm Hg
At sea level (ambient air):
150–Pao_2–1.25×$Paco_2$
Normal anion gap:
Calculate urinary anion gap ([Na^+]+[K^+]–[Cl^-])
If urinary pH>6.5, or urinary [Na+] <20 mmol/liter: evaluate urinary osmolal gap
High anion gap
(e.g., lactate, keto acids, toxic alcohols)
A–a difference ≤10 mm Hg (≤20 mm Hg in elderly)
Hypoventilation without intrinsic lung disease
A–a difference >10 mm Hg (>20 mm Hg in elderly)
Hypoventilation with intrinsic lung disease, ventilation–perfusion mismatch, or both
Urinary anion gap negative
(e.g., diarrhea, sodium infusion, proximal RTA [often hypophosphatemia, hyperuricemia, renal glucosuria])
Urinary anion gap positive: RTA
Type 1: serum [K^+] decrease, urinary pH >5.5
Type 4: serum [K^+] increase, urinary pH >5.5 in hypoaldosteronism
Delta–Delta (Δ–Δ)
Ketoacidosis:
ΔAG–Δ[HCO_3^-]
Lactic acidosis:
Compute the value of [Δ0.6 AG]–[Δ(HCO_3^-)]
If the result is –5 to 5 mmol/liter for either of the above: only high anion-gap metabolic acidosis
>5 mmol/liter: high anion-gap metabolic acidosis as well as metabolic alkalosis
<–5 mmol/liter: high anion-gap metabolic acidosis as well as normal anion-gap acidosis
Osmolal gap
(measured–calculated osmolality) >10 mOsm/kg
(e.g., toxic alcohols)
Calculated serum osmolality:
(2×[Na^+])+[glucose, in mg/dl]/18+(blood urea nitrogen, in mg/dl)/2.8
In standard units
(mmol/liter)=(2×[Na^+])+[glucose]+[urea]

(Source: Physiological Approach to Assessment of Acid–Base Disturbances. N Engl J Med 2014.)



(Source: Physiological Approach to Assessment of Acid–Base Disturbances. N Engl J Med 2014.)

Lactic acidosis from septic shock is the most common acid–base disturbance in the medical ICU. However, if a patient is acidemic, remember to consider other etiologies, including alternative causes of lactic acidosis and acidosis from diabetic ketoacidosis (DKA), toxic ingestions, and other causes.

The use of IV sodium bicarbonate as a buffer in lactic acidosis is controversial. In the 2021 Surviving Sepsis Campaign guidelines, a weak recommendation was made *against* the use of sodium bicarbonate overall to improve hemodynamics or reduce vasopressor requirements. However, its use is suggested in a subset of patients with septic shock, severe metabolic acidemia (pH ≤7.2), and AKI (with AKIN score of 2 or 3) as per the results of the BICAR-ICU trial.

Electrolyte Disturbances

Electrolyte disturbances, including hypokalemia; hyperkalemia; hyponatremia; hypernatremia; and hypomagnesemia, are common in the ICU and can occur as a result of both the underlying condition and the use of resuscitation fluids.

- Electrolyte levels should be corrected to normal ranges in the critically ill to prevent arrhythmia, altered mental status, and other complications.